(12) UK Patent Application (19) GB (11) 2 290 363 (13) A

(43) Date of A Publication 20.12.1995

(21) Application No 9512329.5

(22) Date of Filing 16.06.1995

(30) Priority Data
(31) 4421428 (32) 18.06.1994 (33) DE

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(51) INT CL^6
F16H 1/28 , B60K 1/00 7/00 , F16H 57/08 , H02K 7/116

(52) UK CL (Edition N)
F2Q Q7A3C1E
B7H HDV H513 H564 H741
H2A AKX1 AK111 AK121 AK211 AK215S AK808 AK820
U1S S1820 S2047

(56) Documents Cited
US 4494414 A

(58) Field of Search
UK CL (Edition N) **F2Q**
INT CL^6 **F16H 1/28 57/08 , H02K 7/116**

(54) Drive unit

(57) A drive unit for an individual wheel of a road vehicle includes planetary gearing (3) driven by an electric motor (5, Fig. 1). The planetary gearing (3) comprises a sun wheel (31) seated on a motor spindle (21), an annulus (33) and a planet carrier (37) with planet wheels (41) rotatably mounted on bearing pins (39). The planet carrier (37) and the annulus (33) are connected to a carrier member (9) which forms the housing of the gearing, and an output shaft member (7) which is rotatably mounted on the carrier member (9). The planet carrier (37) includes, a back wall (47) in which are formed integral bearing pins (39). A wall (63) projects from the outer periphery of the back wall (47) in the same direction as the bearing pins (39) and has formed in it teeth (65) for coupling the planet carrier to the carrier member (9) or the output shaft member (7). The planet wheels (41) are held on the back wall (47) by a ring-shaped locating disc (55) which has webs (57) projecting axially from its outer periphery between adjacent planet wheels (41) and welded to the back wall (47).

FIG. 2

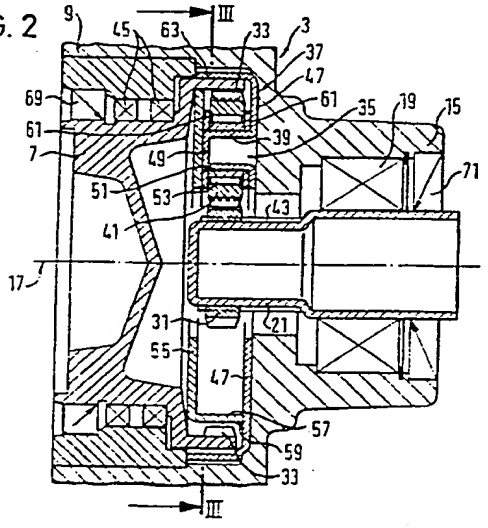

FIG. 3

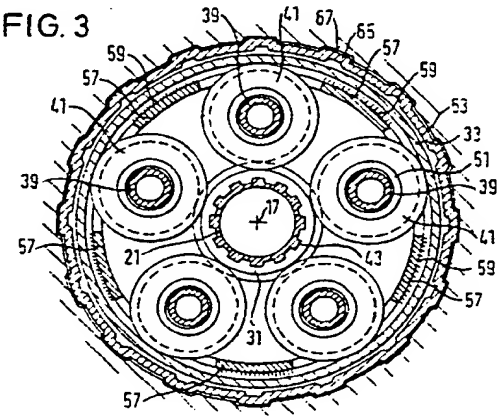

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FIG. 1

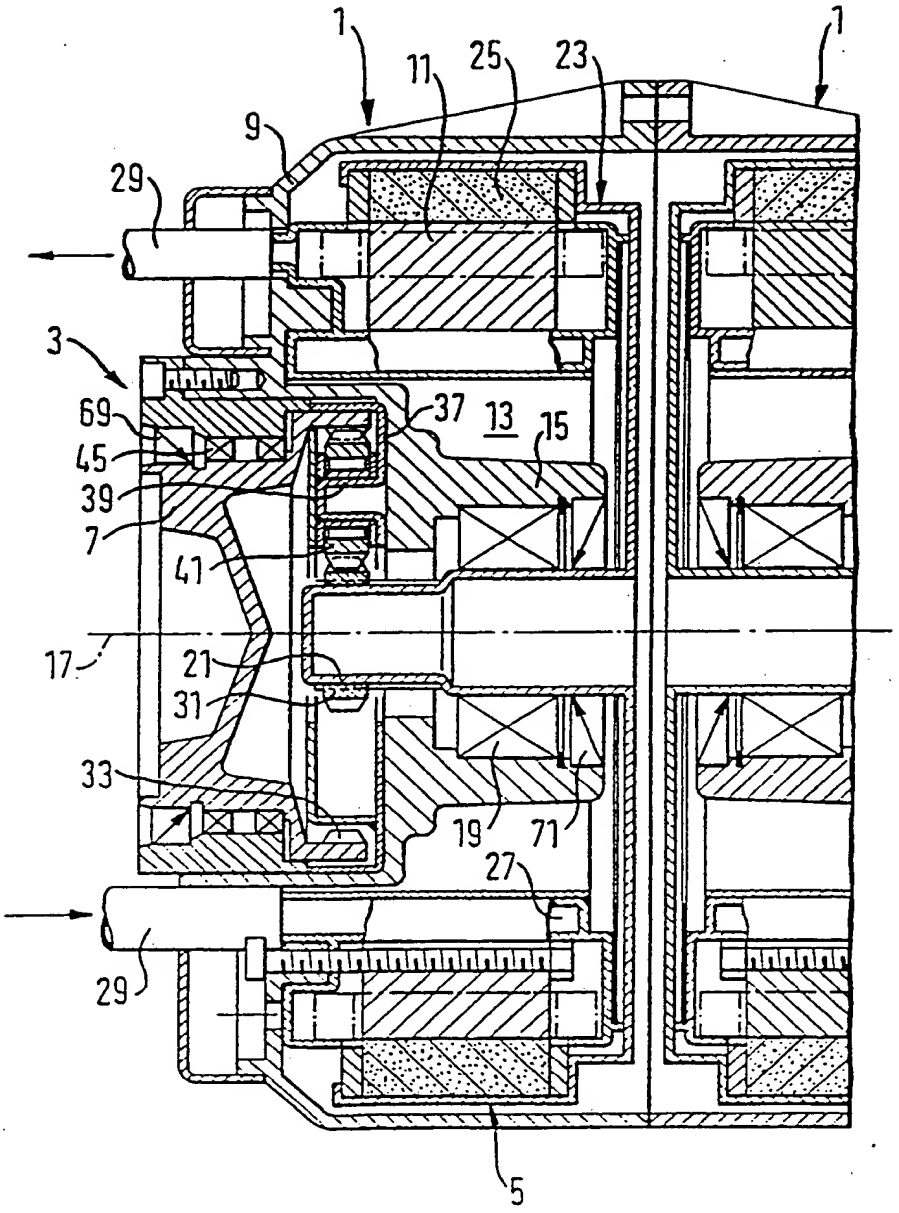

FIG. 2

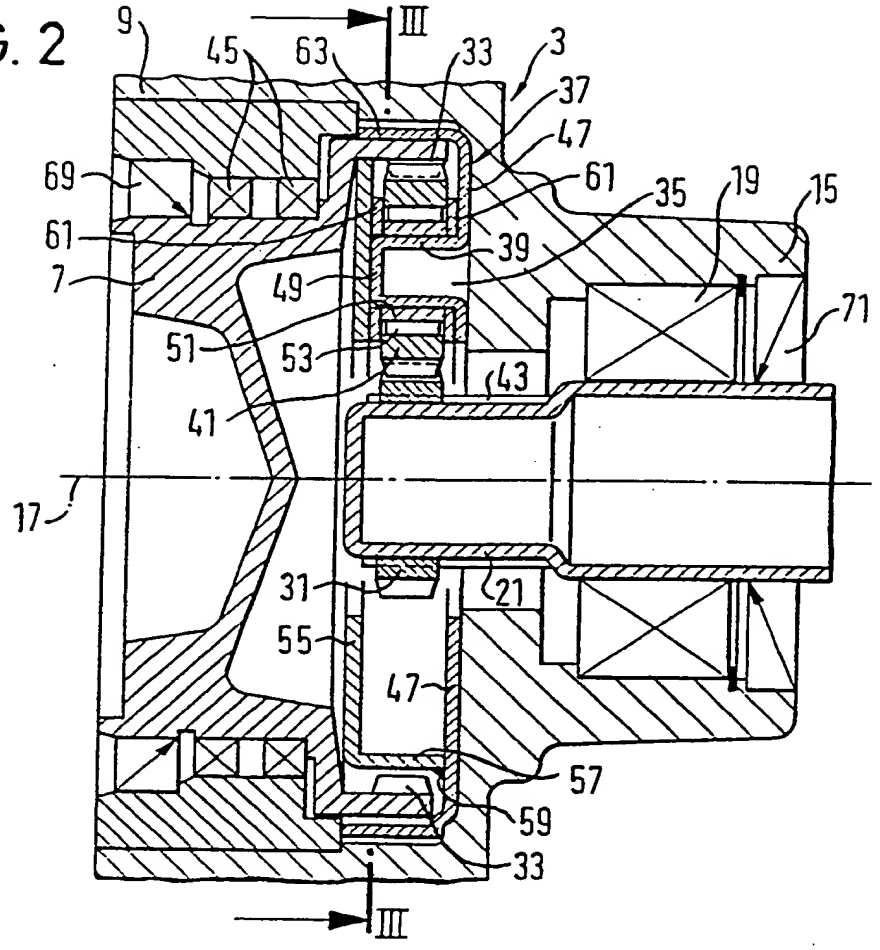
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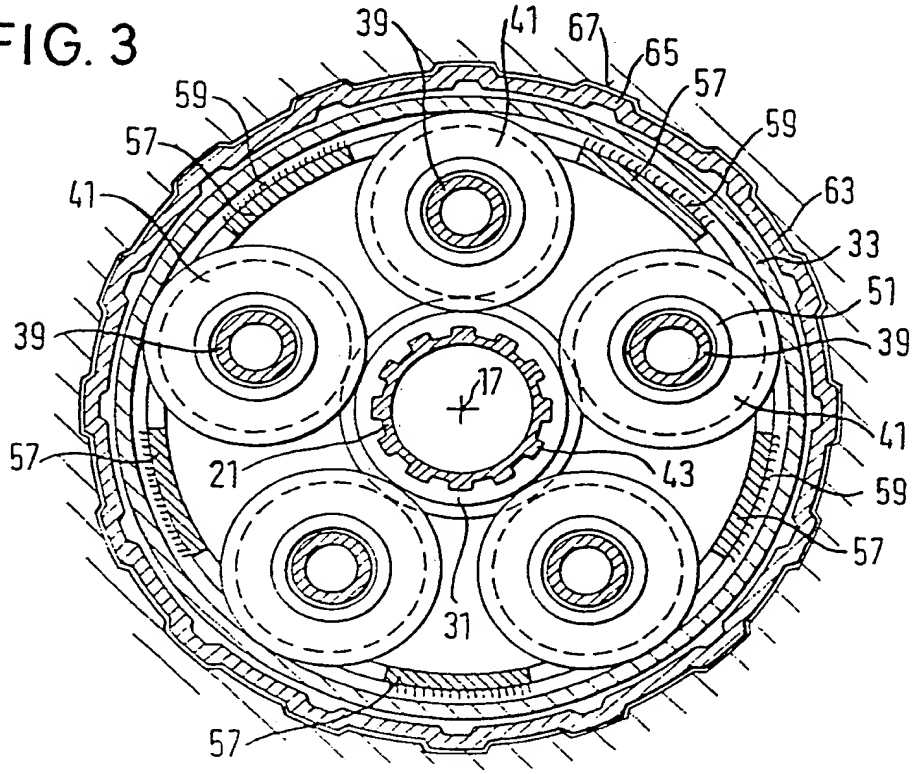
FIG. 3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DRIVE UNIT

The invention relates to a drive unit for driving a rotatable member, and including an electric motor and planetary gearing. The rotatable member may be an individual drive wheel of a road vehicle.

From VDI Report No. 878, 1991, pages 611 to 622 it is known to provide an electric motor for each driving wheel of a road vehicle, each motor being connected to the associated wheel through a cardan shaft. The motors, which have permanent magnet external rotors, are operated through an electric commutator circuit from a generator which in its turn is driven by an internal combustion engine. The driving torque and the speed of the motors is controlled electrically so that mechanical gear boxes and the like, such as are provided between the engine and the driving wheels in orthodox motor vehicles, are unnecessary.

To match the driving torque and the speed of the electric motor to values appropriate for the wheels it is known from EP-A-249 807 to combine each electric motor with a bevel gear drive to form a unit and to incorporate the units in pairs between driving wheels on an axle of the vehicle. In order to reduce the angle of inclination of the cardan shafts which connect the units to the wheels, it is desirable for the cardan shafts to be as long as possible, and then the crown wheel gears are arranged adjacent one another on the side of the

electric motor, also an external rotor motor, which faces away from the associated driving wheel.

It is furthermore known from DE-A-37 25 620, in a road vehicle with an electric motor associated with each individual driving wheel, to arrange the motors axially between the driving wheels to form a unit and to mount a planetary gearing arrangement on the electric motor facing the wheel which it is to drive, the sun wheel being seated on the output shaft of the motor and the carrier for the planet wheels being connected through a cardan shaft to the driving wheel. An annulus which, like the sun wheel, meshes with the planet wheels, is secured relative to the motor through a plate-type brake and when the brake is released it allows the motor to be uncoupled from the wheel.

In orthodox reduction planetary gearing, which reduces the speed from the input side to the output side, the planet wheels are mounted rotatably on pivot pins on a planet wheel carrier which, in its turn, is either mounted with small radial play rotatably on a carrier member or itself is formed as a carrier member. With unfavourable radial tolerances in the planetary gearing the bearing pins can be exposed to high radial deflection forces.

It is an aim of the invention to provide a drive unit including an electric motor and planetary gearing in particular suitable for the individual drive of a wheel of a road vehicle, in which the planet wheel carrier of the planetary gearing is of simpler construction than hitherto.

According to the invention, a drive unit for driving a rotatable member includes an electric motor and planetary gearing, and comprises a carrier member connected to the electric motor, whose output spindle rotates about a drive axis, an output shaft member rotatably mounted on the carrier member for rotation about the drive axis, and the planetary gearing has three gearing components rotatable relative to one another about the drive axis, a first gearing component comprising a sun wheel concentric with the drive axis, a second gearing component comprising an annulus surrounding the sun wheel coaxially and a third gearing component comprising a planet carrier and a number of circumferentially spaced planet wheels mounted on the planet carrier to rotate about axes parallel to the drive axis and meshing with the sun wheel and the annulus, the first gearing component being rotatable with the motor spindle, and the output shaft member and the carrier member each being connected to one of the other two gearing components, and the planet carrier of the third gearing component comprises an annular sheet metal component including a substantially disc-shaped back wall extending substantially perpendicular to the drive axis, the back wall having integrally formed bearing pins for mounting the planet wheel and a set of teeth on its outer periphery for engagement with the output shaft member of the carrier member.

Such a planet carrier is very simple and cheap to manufacture. As the torque which acts on it is transmitted through its external teeth and through

opposing teeth provided on the member which is to be connected to the planet carrier, the planet carrier and thereby the planet wheels mounted rotatably on it can adjust themselves radially in relation to the sun wheel and the annulus. This avoids the radial deflection forces which can arise on bearing pins in conventional planetary gearing. The planet carrier, which is inserted substantially freely in the output shaft member of the carrier member can obviously be located axially, even though with some clearance. The planet wheels can be provided with straight spur teeth or with helical teeth. The slight axial forces produced by the teeth can be handled by the axial location of the planet carrier.

In order to stiffen the sheet metal component and to reinforce the flank faces of the teeth where high torques are to be transmitted the sheet metal component has at its outer periphery a peripheral wall which projects substantially axially from the back wall and in which the teeth are formed. The peripheral wall and the bearing pins preferably project from the back wall in the same axial direction. This keeps the axial space occupied by the gearing small. Preferably the peripheral wall completely overlies the bearing pins in an axial direction. This means that the entire axial structural depth of the planet carrier can be utilised for applying the torque. Where the annulus is connected to the output shaft member, the peripheral wall surrounds at least part of the axial length of the annulus radially outwards.

The planet wheels are preferably axially located on the sheet metal component so that the planet carrier forms a unit which can easily be handled. The planet wheels may each be located on the associated bearing pin for example by retaining rings. In a preferred embodiment it is provided that the sheet metal components carries a locating ring at the ends of the planet wheels axially remote from the back wall to locate the planet wheels axially on the bearing pins. The locating ring preferably comprises an annular disc which can be secured to the bearing pins but is preferably rigidly secured to the back wall by webs extending circumferentially between adjacent planet wheels. In this way the locating ring can be utilised for stiffening the sheet metal component. The webs can be in the form of spacing rivets or the like but are preferably formed integrally on a peripheral edge of the locating ring. It has been found favourable for the webs to be provided on the radially outer peripheral edge as here there is generally more space available between the planet wheels and the webs can therefore be made more stable. The webs can be riveted to the back wall through rivet projections at their ends. However, the planet carrier is stiffened better if the webs are welded to the back wall, preferably over their entire circumferential length. The annular disc forming the locating ring can have holes in which the bearing pins engage loosely or for example are held by spot welds, so that in this way the bearing pins are held at both ends. However, in preferred embodiment the annular disc has an uninterrupted annular body projecting radially on both sides of

the bearing pins. Thereby the annular disc has an unweakened material cross-section which can assist better in stiffening the planet carrier.

As the bearing pins are pressed out of the back wall during the integral formation of the sheet metal component by pressing, they preferably carry bearing sleeves on which the planet wheels are mounted. These sleeves ensure a close-tolerance cylindrical bearing cross-section. The planet wheels may also be mounted through needle roller bearings.

The bearing pins can have the form of open sleeves. However, in order to make the pins as stiff as possible the pins comprise sleeves, each sleeve being closed at its end remote from the back wall by an end plate rigidly connected to the sleeve.

Preferably, the output shaft member is mounted on the carrier member by means of a first roller bearing arrangement on one axial side of the planet wheels, the electric motor comprises an external rotor motor with a ring-shaped stator surrounding a hollow space and a ring-shaped external rotor radially outside the stator, and the carrier member has a bearing extension projecting axially into the space of the stator and surrounding the motor spindle, the motor spindle being rotatably mounted on the side of the planet wheels which is axially remote from the first roller bearing arrangement. Such external rotor motors have relatively small axial dimensions and can despite this be designed

for high output power. Further, the drive unit constructed using such an external rotor motor can be made axially very flat, and the planetary gearing can extend at least partially into the hollow space in the stator so the axial structural length of the unit is reduced.

In this embodiment the carrier member can in addition form a sealed gearbox housing. Thus, the carrier member closely surrounds the radially outer edge of the planetary gearing, and the output shaft member comprises an axially sealed component, sealed with respect to the carrier member by a first rotary seal on the side of the first roller bearing arrangement which is axially remote from the planet wheels, and the motor spindle is sealed with respect to the housing extension by means of a second rotary seal.

An embodiment of the invention by way of example is shown in the accompanying drawings, in which:-

Figure 1 is an axial longitudinal section through a drive assembly for a pair of driving wheels of a road vehicle;

Figure 2 is an enlarged axial longitudinal section of planetary gearing of the drive; and

Figure 3 is an axial cross-section through the planetary gearing taken on the line III-III in Figure 2.

The drive assembly illustrated in Figure 1 comprises two electric motor-gearbox drive units 1 installed on a vehicle between a pair of driving wheels associated with one driving axle of a road vehicle. Each of the two units 1 includes a planetary gearing 3 and an electric motor 5 in the form of a permanent magnet external rotor motor which drives a single wheel of the road vehicle through the planetary gearing 3 and a cardan shaft, not shown, secured to an output shaft member 7 of the planetary gearing. As the two units 1 of the drive assembly are of substantially the same construction only one of the units 1 will be explained in the following.

The drive unit 1 has a carrier member 9, on which is mounted a motor stator 11. The stator 11 is of sheet and is substantially ring-shaped and provided with field windings. The stator 11 encloses a hollow space 13 into which a bearing extension 15 formed on the carrier member 9 projects coaxially with respect to an axis of rotation 17 of the output shaft member 7. A motor spindle 21 is rotatably mounted in the bearing extension 15 by means of a roller bearing arrangement 19 coaxially with respect to the output shaft member 7 and carries on its end remote from the output shaft member 7 a permanent magnet external rotor 23 of the motor 5. The rotor 23 is of substantially pot-like shape, with a peripheral region located radially outwardly of the stator 11 and carries in the peripheral region a number of permanent magnets 25 associated with the poles of the stator 11 and of which the polarity alternates circumferentially. By

means of electronic commutating circuits, not illustrated, connected to the field windings of the stator 11, the power and speed of the motor 5 are controlled.

As the motor 5 is designed for relatively high powers, an annular passage 27 is provided in the space 13 next to the stator 11 for connection through pipes 29 to a coolant circuit.

The planetary gearing 3 includes first gearing component comprising a sun wheel 31 which is mounted on a free end of the motor spindle 21 and is surrounded coaxially by a second gearing component comprising an annulus or internal gear 33 secured on the output shaft member 7. As can be seen best in Figures 2 and 3, a housing chamber 35 in the carrier member 9 surrounds the axis 17 coaxially and houses a third gearing component comprising a planet carrier 37. This is formed as a separate structural unit and includes bearing pins 39, each carrying a planet wheel 41. There are five circumferentially spaced planet wheels 41 shown. The planet wheels 41 mesh with the sun wheel 31, which is seated on the motor spindle 21, through splines 43 and also with the annulus 33 to drive the output shaft member 7, which is mounted rotatably on the carrier member 9 by means of a roller bearing arrangement 45 secured to the output shaft member 7, on that side of the planet wheels 41 which is axially remote from the roller bearing arrangement 19.

The planet carrier 37 comprises a pressed sheet metal component and has a substantially annular

disc-like back wall 47 extending perpendicular to the axis 17 and in which the bearing pins are formed integrally as sleeves with their axes parallel to the axis of rotation 17 and closed to form a pot-shape by end walls 49. Sleeves 51 are fitted over the bearing pins 39 to take up the tolerance and form the inner races for needles 53 of needle roller bearings which locate the planet wheels 41 on the bearing pins 39.

A single locating ring 55 holds all the planet wheels 41 on their respective bearing pins 39 in an axial direction. The locating ring 55 extends parallel to the back wall 47 and projects radially in both directions beyond the bearing pins 39. At the outer periphery of the locating ring 55 there are formed a number of circumferentially spaced axially projecting webs 57 which are arranged in the circumferential spaces between adjacent planet wheels 41 towards the back wall 47 of the component 37, and are welded to the back wall 47 by their free ends at 59 over substantially their entire peripheral lengths. Thrust washers 61 arranged axially on both sides of the planet wheels 41 locate the planet wheels 41 axially on the component 37.

The component 37 is bounded at its radially outer portion by a peripheral wall 63 which projects axially away from the back wall 47 in the same direction as the bearing pins 39. The peripheral wall 63 is formed with teeth 65, which have an associated opposing set of teeth 67 at the peripheral edge of the cavity 35 in the carrier member 9. The teeth hold the component 37 against

rotation in the carrier member 9 whilst allowing radial play. As can be seen in Figure 2, the component 37 is also located axially on the carrier member 9 by the peripheral wall 63. The radial clearance between the component 37 and the carrier member 9 allows the planet carrier component 37 to be guided on the carrier member 9 with substantially balanced forces.

The carrier member 9 also forms with its radially closed chamber 35 a sealed housing which is closed on the wheel side by a closed surface of the output shaft member 7. On the side of the roller bearing arrangement 45 which is axially remote from the planet wheels 41, the output shaft member 7 is sealed with respect to the carrier member 9 by a rotary seal 69. A further rotary seal 71 seals the motor spindle 21 with respect to the bearing extension 15 of the carrier member 9.

The planet carrier (component 37) is easily formed by pressing, and includes the bearing pins 39 for the planet wheels 41, thus reducing the number of components needed. The provision of the planet carrier 37 and the planet wheels 41 as a separate structural unit also simplifies assembly. The arrangement of the planetary gearing in the space 13 in the motor helps to reduce the axial length of the unit 1.

In the embodiment shown, the sheet metal component 37 forming the planet carrier is connected to the carrier member 9 for rotation with it by means of the teeth 65, whereas the internal gear or

annulus 33 is held on the output shaft member 7. In a modification, not shown, the sheet metal component is coupled through its peripheral wall teeth to the output shaft member 7 whilst the annulus is provided on the carrier member 9. In both versions the annulus can be formed on the respective component of the planetary gearing but alternatively it can be secured in its turn through external teeth for rotation with, and axial movement on, the component. This arrangement can be particularly advantageous as the carrier member 9 and output shaft member 7 can have the same construction for both versions.

Claims

1. A drive unit for driving a rotatable member including an electric motor and planetary gearing and comprising a carrier member connected to the electric motor, whose output spindle rotates about a drive axis, an output shaft member rotatably mounted on the carrier member for rotation about the drive axis, and the planetary gearing has three gearing components rotatable relative to one another about the drive axis, a first gearing component comprising a sun wheel concentric with the drive axis, a second gearing component comprising an annulus surrounding the sun wheel coaxially and a third gearing component comprising a planet carrier and a number of circumferentially spaced planet wheels mounted on the planet carrier to rotate about axes parallel to the drive axis and meshing with the sun wheel and the annulus, the first gearing component being rotatable with the motor spindle, and the output shaft member and the carrier member each being connected to one of the other two gearing components, and the planet carrier of the third gearing component comprises an annular sheet metal component including a substantially disc-shaped back wall extending substantially perpendicular to the drive axis, the back wall having integrally formed bearing pins for mounting the planet wheel and a set of teeth on its outer periphery for engagement with the output shaft member of the carrier member.

2. A drive unit as claimed in claim 1, in which the sheet metal component has at its outer periphery a peripheral wall projecting substantially axially

from the back wall and in which the teeth are formed.

3. A drive unit as claimed in claim 2, in which the peripheral wall and the bearing pins project from the back wall in the same axial direction.

4. A drive unit as claimed in claim 2 or claim 3, in which the peripheral wall completely overlies the bearing pins in an axial direction.

5. A drive unit as claimed in any of claims 2 to 4, in which the annulus is connected to the output shaft member and the peripheral wall surrounds at least part of the axial length of the annulus radially outwards.

6. A drive unit as claimed in any preceding claim, in which the sheet metal component carries a locating ring at the ends of the planet wheels axially remote from the back wall to locate the planet wheels axially on the bearing pins.

7. A drive unit as claimed in claim 6, in which the locating ring comprises an annular disc rigidly secured to the back wall by webs extending circumferentially between adjacent planet wheels.

8. A drive unit as claimed in claim 7, in which the webs are formed integrally on a peripheral edge of the locating ring.

9. A drive unit as claimed in claim 8, in which the webs are provided on the radially outer peripheral edge of the locating ring.

10. A drive unit as claimed in any of claims 7 to 9, in which the webs are welded to the back wall.

11. A drive unit as claimed in any of claims 7 to 10, in which the annular disc has an uninterrupted annular body projecting radially on both sides of the bearing pins.

12. A drive unit as claimed in any preceding claim, in which the bearing pins carry bearing sleeves on which the planet wheels are mounted.

13. A drive unit as claimed in claim 12, in which the planet wheels are mounted on the sleeves through needle roller bearings.

14. A drive unit as claimed in any preceding claim, in which the bearing pins comprise sleeves, each sleeve being closed at its end remote from the back wall by an end plate rigidly connected to the sleeve.

15. A drive unit as claimed in any preceding claim, in which the output shaft member is mounted on the carrier member by means of a first roller bearing arrangement on one axial side of the planet wheels, the electric motor comprises an external rotor motor with a ring-shaped stator surrounding a hollow space and a ring-shaped external rotor radially outside the stator, and the carrier member has a

bearing extension projecting axially into the space of the stator and surrounding the motor spindle, the motor spindle being rotatably mounted on the side of the planet wheels which is axially remote from the first roller bearing arrangement.

16. A drive unit as claimed in claim 15, in which the external rotor is a permanent magnet rotor.

17. A drive unit as claimed in claim 15 or claim 16, in which the carrier member closely surrounds the radially outer edge of the planetary gearing, and the output shaft member comprises an axially sealed component, sealed with respect to the carrier member by a first rotary seal on the side of the first roller bearing arrangement which is axially remote from the planet wheels, and the motor spindle is sealed with respect to the housing extension by means of a second rotary seal.

18. A drive unit driving a rotatable member and including an electric motor and planetary gearing substantially as described herein with reference to and as illustrated in the accompanying drawings.

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ıtents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9512329.5
Relevant Technical Fields (i) UK Cl (Ed.N) F2Q (ii) Int Cl (Ed.6) F16H 1/28, 57/08; H02K 7/116	Search Examiner A HABBIJAM Date of completion of Search 20 JULY 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 1 TO 18

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Y:	Document indicating lack of inventive step if combined with one or more other documents of the same category.	**E:**	Patent document published on or after, but with priority date earlier than, the filing date of the present application.
A:	Document indicating technological background and/or state of the art.	**&:**	Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
A	US 4494414 (HAMANO) see Figure 2 of the drawings	1

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